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Understanding facial emotion perception in Parkinson's disease: The role of configural processing

Pauline Narme[a,*], Anne-Marie Bonnet[b], Bruno Dubois[b,c], Laurence Chaby[d,e]

[a] EA 4559, Laboratoire de Neurosciences Fonctionnelles et Pathologies, Université Picardie Jules Verne, 3 rue des Louvels, Amiens 80036, France
[b] Service de Neurologie, AP-HP, Hôpital Pitié-Salpêtrière, Paris, France
[c] Institut de la Mémoire et la Maladie d'Alzheimer, UMR S975, Paris, France
[d] Cnrs, UMR 7222, Institut des Systèmes Intelligents et de Robotique, Paris, France
[e] Université Paris Descartes, Sorbonne Paris Cité, Institut de Psychologie, Boulogne-Billancourt, France

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ABSTRACT

Parkinson's disease (PD) has been frequently associated with facial emotion recognition impairments, which could adversely affect the social functioning of those patients. Facial emotion recognition requires processing of the spatial relations between facial features, known as the facial configuration. Few studies, however, have investigated this ability in people with PD. We hypothesized that facial emotion recognition impairments in patients with PD could be accounted for by a deficit in configural processing. To assess this hypothesis, three tasks were proposed to 10 patients with PD and 10 healthy controls (HC): (i) a facial emotion recognition task with upright faces, (ii) a similar task with upside-down faces, to explore the face inversion effect, and (iii) a configural task to assess participants' abilities to detect configural modifications made on a horizontal or vertical axis. The results showed that when compared with the HC group, the PD group had impaired facial emotion recognition, in particular for faces expressing anger and fear, and exhibited reduced face inversion effect for these emotions. More importantly, the PD group's performance on the configural task to detect vertical modifications was lower than the HC group's. Taken together, these results suggest the presence of a configural processing alteration in patients with PD, especially for vertical, second-order information. Furthermore, configural performance was positively correlated with emotion recognition for anger, disgust, and fear, suggesting that facial emotion recognition could be related, at least partially, to configural processing.

1. Introduction

Parkinson's disease (PD) is a neurodegenerative disorder characterized by a loss of dopaminergic neurons in the ventral striatum, subthalamic nucleus and other basal ganglia structures. Although its classical expression is characterized by motor disorders (for a review, see Lang & Lozano, 1998), PD is also frequently associated with cognitive deficits such as memory (for a meta-analysis, see Whittington, Podd, & Kan, 2000), visuo-spatial (Crucian & Okun, 2003), and executive disturbances (e.g., McKinlay, Grace, Dalrymple-Alford, & Roger, 2010). Behavioral and communicative disorders can also complicate the clinical presentation (Schneier et al., 2000). Indeed, impairment of emotional control (Dujardin et al., 2004; Yamamoto, 2001), apathy (Levy & Dubois, 2006; Pluck & Brown, 2002), anxiety disorders and, more rarely, hallucinations or psychosis (for a review see Aarsland, Marsh, & Schrag, 2009) may appear during the course of the disease.

Because of the evidence that the ventral striatum and subthalamic nucleus have connections with other brain regions, including the orbitofrontal cortex, the amygdala and the putamen (see Adolphs, 2002; Fusar-Poli et al., 2009 for reviews), emotional processing has been widely studied in patients with PD over the last two decades. Several studies (see Gray & Tickle-Degnen, 2010 for a meta-analysis) have shown specific impairments in patients' capacity to recognize emotions from facial cues (Clark, Neargarder, & Cronin-Golomb, 2008; Dujardin et al., 2004; Sprengelmeyer et al., 2003), prosodic cues (Pell & Leonard, 2003; Yip, Lee, Ho, Tsang, & Li, 2003) or both (Ariatti, Benuzzi, & Nichelli, 2008; Dara, Monetta, & Pell, 2008).

Given that the ability to interpret other people's emotional states from facial cues plays a crucial role in social behaviors (Darwin, 1965; Carton, Kessler, & Pape, 1999), facial emotional processing impairments could adversely affect the social functioning of patients with PD. Though obtaining a better comprehension of the mechanisms involved in such deficits may pose significant

* Corresponding author. Tel.: +33 0 3 22 82 54 42.
E-mail addresses: paulinenarme@gmail.com, pauline.narme@u-picardie.fr (P. Narme).

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clinical challenges, some of the uncertainties that remain must be addressed. First, it is not yet clear whether the emotion recognition deficit is specific for disgusted (e.g., Suzuki, Hoshino, Shigemasu, & Kawamura, 2006) or angry expressions (Lawrence, Goerendt, & Brooks, 2007) or whether it generally concerns negative emotions (e.g., Clark et al., 2008; Kan, Kawamura, Hasegawa, Mochizuki, & Nakamura, 2002; see Gray and Tickle-Degnen for a meta-analysis). Second, facial emotion recognition deficit appears not to be related to executive functions such as categorization (Clark et al., 2008) or working memory abilities (see Gray & Tickle-Degnen, 2010). Facial emotion recognition requires, however, the ability to discriminate facial features, and the visuospatial processing impairments reported in PD patients (Levin, Llabre, Reisman, & Weiner, 1991) could at least partially lead to a facial emotion recognition deficit.

Initially, Bruce and Young (1986) model of face recognition posited that processing facial emotion and facial identity were two independent functional components. Arguing against this hypothesis, more findings have actually suggested that identity and emotion recognition interact (see Vuilleumier & Pourtois, 2007 for a review). Both processes could, in fact, share some perceptual encoding mechanisms (Calder, Young, Keane, & Dean, 2000; Calder & Jansen, 2005). Configural processing, by which the brain understands the spatial relations between facial features (Carey & Diamond, 1977; Diamond & Carey, 1986), is crucial for identifying faces. It includes first-order relations (i.e. overall organization of facial features) and second-order relations (i.e., distances between features, e.g., inter-ocular distance; for a review, see Maurer, Le Grand, & Mondloch, 2002). The former refers to holistic information that is the integration of the facial features into a Gestalt, to identify the target as a face, while the latter is more relevant to facial identity recognition (Maurer et al., 2002; Rossion, 2008). Both information are altered when faces are presented upside-down, inducing a recognition decrement (Yin, 1969; for a review, see Rossion, 2008). This so-called 'Face Inversion Effect' (FIE) has been widely explained as a disruption of configural processing, inverted-face being insufficiently processed through its local elements (Freire, Lee, & Symons, 2000; George, Jemel, Fiori, Chaby, & Renault, 2005; Goffaux & Rossion, 2007; Leder & Bruce, 2000; see also Rossion, 2008). When individuals show a defect of processing configural information, for example in acquired prosopagnosia, upright recognition or discrimination of faces differing by second-order relations are decreased, while performance are less or not at all affected by inversion (Barton, Press, Keenan, & O'Connor, 2002). In such a case, the FIE is reduced or even suppressed.

Yet, a similar FIE has been reported using facial emotion recognition tasks (Calder & Jansen, 2005; McKelvie, 1995; Prkackin, 2003). Turning pictures of facial expressions upside-down has been found to impair recognition performance (McKelvie, 1995), especially for angry, disgusted and fearful faces (Prkackin, 2003). These results suggest that (i) configural processing is also used to encode facial expressions and (ii) expressions of anger, disgust, and fear more heavily tax a person's configural processing resources. Thus, as was suggested many years ago (Ekman, Friesen, & Ellsworth, 1972; McKelvie, 1973), facial emotion recognition requires configural processing rather than a simple inspection of various facial features. For example, in an expression of anger, the shape and position of the mouth may be coded relative to the shape and position of other features (e.g., the eyebrows, Calder et al., 2000). Arguing for this hypothesis, functional neuroimaging studies have shown that fusiform gyri, involved in the structural encoding of faces, are activated when facial expressions are presented (Vuilleumier & Pourtois, 2007). In addition, although dissociations exist, face recognition impairments and facial emotion recognition deficits have been found to correlate in various diseases, such as bilateral amygdala lesions (Young, Hellawell, Van de Wal, & Johnson, 1996), autism (see Behrmann, Thomas, & Humphreys, 2006 for a review) and schizophrenia (Chambon, Baudouin, & Franck, 2006).

Few studies have investigated facial processing skills in PD patients. Using various perception tasks (unfamiliar matching task, perception of age, gender or gaze direction), previous studies have shown a relatively spared facial identity processing in PD patients (Clark et al., 2008; Lawrence et al., 2007; Sprengelmeyer et al., 2003, see also Gray & Tickle-Degnen, 2010 for a meta-analysis). In contrast, some reports argue that PD patients demonstrate a general impairment in their ability to recognize or perceive faces (Beatty et al., 1989; Dewick, Hanley, Davies, Playfer, & Turnbull, 1991; Haeske-Dewick, 1996; Levin et al., 1991), especially when tasks used more directly involved configural processing (Cousins, Hanley, Davies, Turnbull, & Playfer, 2000). For example, configural processing as assessed by identification of degraded faces was specifically disrupted in PD patients, while part-based object processing was intact (Cousins et al., 2000). Thus, PD could be associated with more basic defects in the structural encoding of faces, and more specifically in configural processing (Beatty et al., 1989; Cousins et al., 2000; Dewick et al., 1991; Haeske-Dewick, 1996). Some evidence have been provided supporting this hypothesis: (1) visuospatial processing impairments are common in PD (Crucian & Okun, 2003; Crucian et al., 2010; Ey et al., 2005); (2) the global processing may be altered in PD, even whether it seems dependent of the body side of motor onset (Schendan, Amick, & Cronin-Golomb, 2009; see also Cronin-Golomb, 2010); (3) a configural processing impairment has been reported in PD while viewing degraded neutral faces (Cousins et al., 2000); and (4) basal ganglia are connected to fusiform regions (Geday, Ostergaard, & Gjedde, 2006) which are involved in face processing (Kanwisher, McDermott, & Chun, 1997). Moreover, configural processing seems crucial for facial emotion recognition (Calder & Jansen, 2005; Calder et al., 2000; McKelvie, 1995; Prkackin, 2003). Thus, we hypothesized that the deficit in facial emotion recognition in patients with PD could be accounted for by a deficit in their configural processing abilities. Nevertheless, although recent studies on the emotional processing deficits in PD patients do exist, to the best of our knowledge, no study has investigated the structural encoding abilities of PD patients by directly manipulating facial configuration yet (e.g. by changing distances between facial features), in relation to emotion processing.

To assess this hypothesis, three tasks were proposed: (i) a facial emotion recognition task, (ii) an upside-down facial emotion recognition task to assess the face inversion effect, and (iii) a configural task to assess the processing of second-order information in neutral faces. We hypothesized that performance on the facial emotion identification task would be lower for the PD group than for the healthy controls, especially for negative emotions, and that the PD group would show a reduced classic FIE for emotion recognition. Whether configural processing is impaired, detection of feature displacements should also be more difficult for patients than for healthy controls. Finally, whether facial emotion recognition impairment in PD is linked to changes in configural processing, performance on these two tasks should be correlated.

2. Method

2.1. Participants

Twelve patients suffering from idiopathic Parkinson's disease (PD) took part in the study. All patients met the clinical criteria of the United Kingdom Parkinson's Disease Society Brain Bank for Idiopathic PD (Hughes, Daniels, Kilford, & Lees, 1992) and received their diagnosis from a movement disorder specialist (AM.B) in the Pitié-Salpêtrière Hospital (Paris, France). The severity of the disease in each participant was rated using the Hoehn and Yahr (1967) scale. All of the participants were within the stage I–stage III (mild unilateral to moderate bilateral disability) at the time of testing. Nine patients had right body side onset of motor symptoms and three had left side onset. All of the patients were undergoing dopamine replacement therapy and were tested while being administered their anti-parkinsonian medication (i.e.,

Table 1
Participants' sociodemographics characteristics and neuropsychological assessment. PD, Parkinson's disease patients; HC, healthy controls; M, mean; SD, standard deviation (or range when indicated).

	PD group ($n = 10$) M (SD)	HC group ($n = 10$) M (SD)	p value[a]
Age (year)	63.2 (8.3)	63.1 (5.5)	.91
Male–female	8–2	7–3	.61[b]
Education (year)	12.9 (4.9)	13.8 (5.1)	.57
Disease duration (years)	9.8 (3.7)	–	
Hoehn and Yahr score	2.1 (range 1–3)	–	
Motor-side onset (L/R)	3/7		
Mini-mental state exam (/30)	28.5 (1.6)	29.1 (1.0)	.43
Dementia rating scale (/144)	139.9 (3.8)	141.1 (2.8)	.50
Montgomery and Asberg Depression Rating Scale (/60)	7.9 (4.9)	5.6 (4.6)	.29
FAB (/18)	15.4 (2)	–	
VOSP cube subtest (/10)	9.5 (0.5)	9.5 (0.5)	1.0
Judgment of line orientation test (/30)	24.3 (2.3)	25.7 (2.6)	.23
Choice reaction time (ms)	598 (84)	976(139)	.71

[a] p value: Mann–Whitney U test.
[b] (or χ^2 when indicated).

during their "on" state). Patients who had neurological complication factors (e.g., vascular lesions) or who had undergone deep brain stimulation were not included in the study. Patients who met dementia criteria (Emre et al., 2007) or who scored below the cutoff of 132 on the Dementia Rating Scale (DRS, Mattis, 1988) and/or the cutoff of 26 on the Mini-Mental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975) were excluded ($n = 2$). The remaining ten PD patients were included.

Ten healthy controls (HC) were recruited from the patient's relatives or from the Paris community. These participants were free of psychiatric or neurological disorders, had no family history of Parkinson's disease, and displayed no signs of dementia (as attested by their MMSE score, in confrontation with French normative data, Kalafat, Hugonot-Diener, & Poitrenaud, 2003). The PD group and the HC group were matched for age and education level. The characteristics of both groups are presented in Table 1.

All participants spoke French as their native language, were right-handed and had normal or corrected-to-normal vision. All participants gave their written informed consent prior to their inclusion in the study and were allowed to withdraw at any time.

2.2. Design and procedures

All experimental tasks were created with E-Prime 1.1 (Psychology Software Tools, Inc., Pittsburgh, PA) and presented on a 17 in. monitor (resolution set to 1280 × 768 pixels)

2.2.1. Neuropsychological assessment

Before the experimental tasks, a battery of neuropsychological tests was used to assess different aspects of cognitive functioning in both patients and controls (except for executive functions only assessed for the PD group). Global cognitive efficiency was rated using the MMSE and the DRS. Current level of depression was estimated using the Montgomery and Asberg Depression Rating Scale (Montgomery & Asberg, 1979). The Frontal Assessment Battery (FAB, Dubois, Slachevsky, Litvan, & Pillon, 2000) was used to assess executive functions in patients with PD. We added the Benton Judgment of Line Orientation Test (Benton, Hasher, Varney, & Spreen, 1983), which provided an evaluation of the participant's visuospatial functions that could have subsequent consequences on face processing. In this test, a pair of partial lines was presented to participants. They had to choose, from among eleven lines drawn at different orientations (from 0° to 180°) displayed on a multiple-choice response card, the lines that correspond to the pair's orientation. We also proposed the cube subtest of the Visual Object and Space Perception Battery (VOSP; Warrington & James, 1991), in which participants were asked to determine the number of cubes in ten figures.

Finally, a choice reaction time task was administered to control for slowing in the PD patients. A triangle or circle was displayed at the center of a screen, and participants were asked to press the corresponding button (i.e., left or right for half of the participants and right or left for the other half) according to the type of stimulus that appeared. Stimuli were presented in a random order for 40 trials (20 triangles/20 circles). Reaction times for accurate responses were recorded.

2.2.2. Facial expression recognition tasks

Ten black and white photographs of faces (five female) were taken from the Ekman series (Ekman & Friesen, 1976). Each face was presented expressing four basic emotions, chosen to be significantly disturbed in PD (happiness, fear, disgust, and anger), plus a neutral expression for a total of 50 photographs. Sadness was not selected because of possible depression interferences (for a review, see Bediou, Saoud, Harmer, & Krolak-Salmon, 2009). The images were cropped so that only the facial regions were shown, and they were placed on a black background using Adobe Photoshop software. All photographs were displayed on a 17 in. computer screen within an area of 500 × 500 pixels (12.9 cm × 13.5 cm). The participants were required to (i) identify the emotions expressed on a set of 50 upright faces (Fig. 1A), and (ii) identify the emotions expressed on a set of 50 upside-down faces (this task was used to assess configural processing of facial emotion and to calculate the FIE, Fig. 1A). Before the experimental procedure, semantic knowledge about each emotional concept was rated; participants were asked to briefly describe a situation in which these basic emotions could be experienced.

In the upright task, each of 50 upright photographs was presented in pseudo-random order. The photograph remained on the screen until the participant selected one of the five emotion labels (listed above) that best described the emotion shown on each face and gave a verbal response. Correct responses were recorded on a score sheet. The upside-down task procedure was identical to upright one. The order of upright and upside-down tasks was counterbalanced across participants and was preceded by a training phase, allowing the participants to become familiar with the task's principles before the test sessions.

2.2.3. Facial configuration detection task

Eight photographs of neutral faces, selected from the lifespan database (Minear & Park, 2004) and balanced for age (young, old) and gender (males, females), constituted the original stimuli. Using Adobe Photoshop software, photographs were cropped so that only the face was visible. This cropped image was placed on a black background, and a Gaussian blur was applied to make the skin look smooth and to facilitate feature displacement (for the detailed procedure, see Chaby, Narme, & George, 2011; see also Fig. 1B). Each original face was modified in four ways (referred to as "twins") by moving the eyes apart or closer to each other (horizontal modifications) or by changing the eyes–mouth distance in the same way (vertical modifications). Thus, a total of 32 (8 × 4) modified faces were created. The magnitude of feature displacement was 14 pixels (3.7 mm) in each condition (i.e., moving eyes up and mouth down by 7 pixels each). This magnitude was chosen according to the results our previous study, which showed that smaller displacements made the detection task difficult, even for elderly participants (Chaby et al., 2011). We also wanted to introduce distortions that looked natural. All stimuli were framed within an area of 500 × 500 pixels (12.9 cm × 13.5 cm), corresponding to a visual angle of around 9° × 10° at a viewing distance of 80 cm. A visual angle of this range was chosen consistently with previous studies using a similar visual angle (or even smaller) in healthy controls (e.g. Collignon et al., 2010; Goffaux, 2009) as in patients (e.g.; Linden et al., 2010; Subramanian, Hindle, Jackson, & Linden, 2010).

After familiarization, the experiment began. It consisted of one block of 64 trials: 32 "same" trials (8 original faces × 4 repetitions) and 32 "different" trials (8 original faces × 4 modifications). At the beginning of each trial, a fixation cross appeared at the center of the screen for 500 ms, followed by an original face (target), which appeared for 2000 ms. After an inter-stimulus interval of 500 ms, a second face (probe) was displayed for 5000 ms, being either the same original face or one of the 4 modified versions of that face (see Chaby et al., 2011). The task was to decide whether the target and the probe stimuli were the 'same' or 'different' faces; the participant would indicate their choice by pressing the corresponding button (i.e., left or right respectively; the position was counterbalanced across participants). Finally, an inter-trial interval was presented for 2000 ms. The order of the trials was pseudo-randomized. Every 8 trials there was a short break (8 blocks of 8 trials).

2.3. Data analysis

Given the small sizes of the samples, performances were compared using non-parametric tests. The Mann–Whitney U test was used for comparisons between the PD group's and the HC group's mean performance, both on neuropsychological measures and on each experimental task separately. The Bonferroni correction was used for multiple comparisons. Friedman ANOVA was used to investigate within-subjects effects, with post hoc Wilcoxon pairwise comparisons using Bonferroni correction. The statistical level of significance was set at .05 (or adjusted statistical level as indicated according to the analysis). All values are expressed as means ± standard error of the means (SEM)

3. Results

3.1. Group characteristics and neuropsychological measures

The PD group did not differ significantly from the HC group in their sociodemographic characteristics and neuropsychological measures (see Table 1). Depression scores were slightly higher in PD group, but this difference did not reach significance. Analyses conducted on mean choice reaction time showed that PD patients were not significantly slower than the HC ($U = 45$, $z = 0.38$, $p = .71$). The FAB score in our PD group was below the normative values

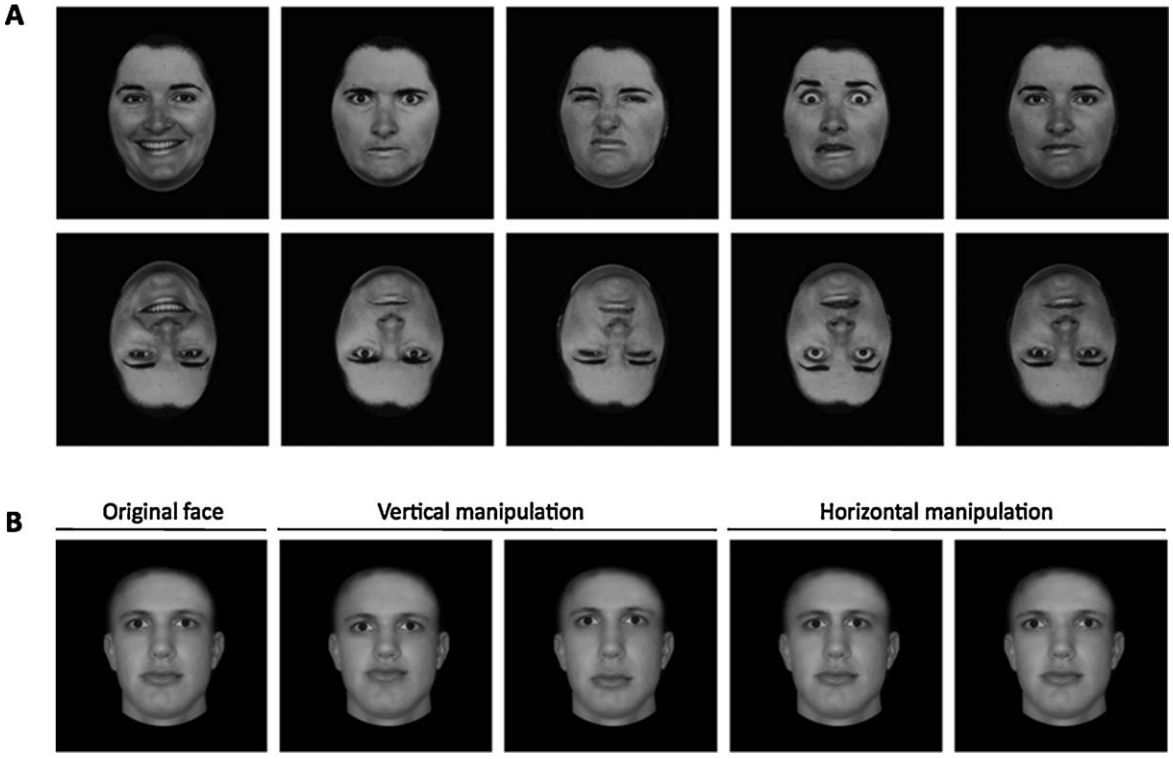

Fig. 1. An illustration of the two tasks (A) facial expression recognition task with four basic emotions (happiness, fear, disgust, anger and neutral) in upright and upside-down conditions; (B) facial configuration detection task, with an example (from the left to the right columns') of: original face, vertical manipulation, horizontal manipulation (see also Chaby et al., 2011).

(Z-score = −2.4) suggesting executive dysfunction, similarly to PD patients in the validation study (Dubois et al., 2000).

3.2. Facial expression recognition task

A Mann–Whitney U test was used to compare PD group's and HC group's mean accuracy, which showed a lower accuracy for the PD group than the HC group in the upright condition only (for upright faces, 81.0 ± 3.1% versus 94.2 ± .9%, U = 11, z = −2.95, p = .003; for upside-down faces, 65.4 ± 3.6% versus 62.0 ± 3.9%, U = 44, z = 0.45, p = .7). To examine the error patterns, a stimulus–response contingency table was produced based on the results of the two groups' performance in both upright and upside-down conditions (Table 2). The emotion category depicted by a stimulus is shown in the rows and the mean percentage of given responses is shown in the columns. Diagonals (in bold) indicate the mean percentage accuracy for each emotion category, and others cells indicate misclassification errors. A Mann–Whitney U test was used to compare PD group's and HC group's accuracy for each emotion, using Bonferroni correction for multiple comparisons (statistical level of significance: p = .05/6 = .008). For upright faces, mean accuracy was significantly lower for anger in PD (56 ± 27.2) than HC (90 ± 8.2, U = 6.5, z = −3.29, p = .001; all other comparisons p > .1). For upside-down faces, any significant group difference was found (all p > .1).

Nevertheless, a visual analysis of Table 2 suggests that there was some bias in the participants' responses. For example, the PD group correctly classified 56% of the upright anger stimuli as "anger", but misclassified 24% of the upright anger stimuli as "fear", 17% as "disgust" and 3% as "neutral". In general, "neutral" and "anger" responses were incorrectly given (false alarms) more often than other responses, especially when faces were presented upside-down. Thus, a high percentage of correct responses for a given emotion could result either from high accuracy or from a bias toward this emotion (higher rate of false alarms). To take both hits and false alarms into account, d' and C indexes from signal detection theory (Mcmillan & Creelman, 2005) were computed. d' is an index of discriminability; it corresponds to the participants' ability to (mis)identify the target emotion. d' ranges from 0 (no discrimination) to infinity (perfect discrimination), and a value higher than 3 is usually considered to reflect a good discriminability. C is an index of bias; it indicates the participant's decision criterion, which can

Table 2
Stimulus–response contingency table showing mean percentage of correct response for each emotion category, in PD patients and HC participants on upright and upside-down conditions.

Group		Response categories				
Orientation	Stimuli	Happiness	Anger	Disgust	Fear	Neutral
HC						
Upright	Happiness	**99**	0	0	0	1
	Anger	0	**90**	3	7	0
	Disgust	0	6	**93**	1	0
	Fear	1	2	4	**93**	0
	Neutral	0	1	3	0	**96**
Upside-down	Happiness	**89**	1	0	1	9
	Anger	10	**39**	13	10	27
	Disgust	1	22	**62**	6	9
	Fear	8	30	5	**42**	15
	Neutral	2	3	4	13	**78**
PD						
Upright	Happiness	**97**	0	0	0	3
	Anger	0	**56**	17	24	3
	Disgust	0	11	**83**	5	1
	Fear	1	14	7	**78**	0
	Neutral	0	0	1	4	**95**
Upside-down	Happiness	**88**	1	1	1	9
	Anger	6	**36**	17	12	29
	Disgust	2	11	**59**	8	20
	Fear	6	16	4	**60**	14
	Neutral	2	2	3	9	**84**

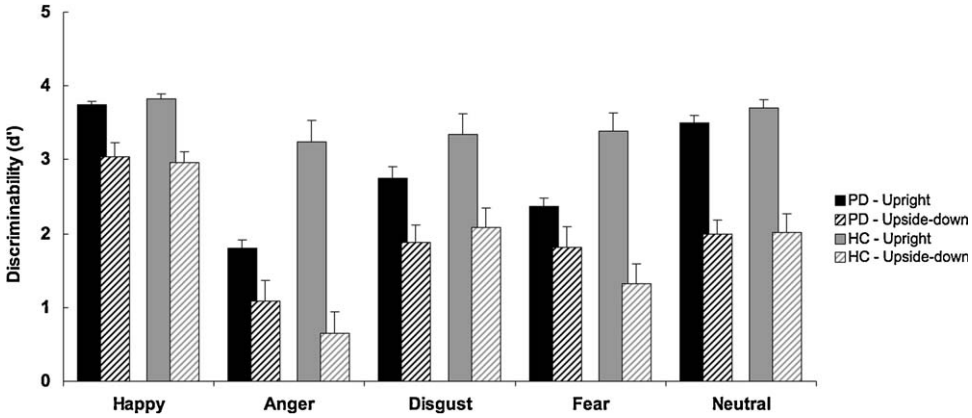

Fig. 2. Discriminability (d') for each emotion, by orientation and group (error bars correspond to standard errors).

be liberal (the participant tends to "recognize" the emotion even in other emotions) or conservative (the participant tends not to recognize the emotion). *C* ranges from −1 (liberal criterion) to 1 (conservative criterion), with the value 0 indicating a neutral criterion.

3.2.1. Discriminability d′

d' values for each group in each condition (upright and upside-down faces) and for each emotion are presented in Fig. 2.

A Mann–Whitney *U* test was used to compare PD group's and HC group's discriminability for each emotion, using Bonferroni correction for multiple comparisons (statistical level of significance: $p = .05/6 = .008$). For upright faces, discriminability was significantly lower in the PD than in the HC group for angry ($d' = 1.80$ versus $d' = 3.24$, $U = 8$, $z = 3.17$, $p = .001$) and fearful expressions ($d' = 2.37$ versus $d' = 3.38$, $U = 12$, $z = 2.87$, $p = .004$) but not for other emotions (all $p > .1$). Note that the HC group had a high discriminability for all emotions (all $d' > 3$), whereas in the PD group, only happy and neutral emotions obtained such rates. A Friedman's ANOVA was conducted in each group to determine whether some emotions were better discriminated than others. In HC, discriminability differed according to the emotion (χ^2 (4) = 14.54, $p = .006$). Post hoc analysis with Wilcoxon tests was conducted with a Bonferroni correction (significant level set at $p = .05/6 = .008$). Happy expressions ($d' = 3.82$) significantly differed than angry expressions ($d' = 3.24$ $p = .007$) and others expressions did not differ. In PD, discriminability also differed according to emotion displayed (χ^2 (4) = 29.97, $p < .001$). Discriminability was higher for happiness ($d' = 3.75$), neutral ($d' = 3.50$) and disgust ($d' = 2.74$) than fear ($d' = 2.37$, all $p < .008$), followed by anger ($d' = 1.80$, $p = .007$).

For upside-down faces, discriminability did not significantly differ between the PD and HC groups for any specific emotion (all $d' \leq 3$ and all $p > .3$). Discriminability also differed according to the emotion within HC (χ^2 (4) = 30.32, $p = .001$) as well as PD (χ^2 (4) = 21.73, $p = .001$). Wilcoxon tests revealed a similar pattern in each group, showing that happiness (PD: $d' = 3.04$; HC: $d' = 2.96$) was better recognized than neutral, disgust and fear (respectively, PD: $d' = 1.99$; HC: $d' = 2.01$, all $p < .008$; PD: $d' = 1.89$; HC: $d' = 2.08$, all $p = .007$; PD: $d' = 1.82$; HC: $d' = 1.32$, $p < .008$). Anger was the least recognizable emotion (PD: $d' = 1.09$; all $p < .008$; HC: $d' = .66$, all $p < .008$).

The FIE was calculated by subtracting the mean accuracy (expressed in percentage) given for upside-down facial expressions from the mean accuracy in the classic upright facial expression recognition task (Table 3). A Mann–Whitney test with Bonferroni correction (statistical level of significance: $p = .05/6 = .008$) showed that the PD and HC groups differed on the mean FIE regardless the emotion ($U = 15$, $z = -2.65$, $p = .008$), but group difference on FIE was significant in anger ($U = 13$, $z = 2.80$, $p = .04$) and fear ($U = 9$, $z = 3.10$, $p = .02$), which were both larger in the HC group.

3.2.2. Decision criterion C

For upright faces, the criterion was more conservative for the PD than the HC group (0.40 versus 0.33, $U = 12.5$, $z = 2.83$, $p < .01$). A Mann–Whitney *U* test was used to compare PD group's and HC group's decision criteria for each emotion, using Bonferroni correction for multiple comparisons (statistical level of significance: $p = .05/6 = .008$). The criterion did not significantly differ between the two groups for upright and upside-down faces (all $p > .07$).

3.3. Facial configuration detection task

Because same–different tasks are prone to response biases, the number of hits and false alarms was calculated for each participant to compute the discriminability index (d'). The mean reaction time for hits was also computed for each participant. The HC group obtained a mean d' of 2.11, and the mean reaction times (RTs) were 1065 ± 82 ms. In contrast, the PD patients obtained a mean d' of 1.03, and their mean reaction times were 1398 ± 100 ms. Statistical analysis revealed that the PD patients had significantly lower overall discriminability ($U = 12$, $z = -2.87$, $p < .01$) and slower RTs ($U = 19$, $z = 2.34$, $p < .05$) than the HC group.

To explore if this difficulty in detecting slight feature displacements depends on whether the manipulations were made on the horizontal or the vertical axis (see Table 4), we conducted non-parametric analyses on accuracy (correct responses) and the corresponding reaction times (RTs) for each modification type, with Bonferroni correction for multiple comparisons (statistical level of significance: $p = .05/2 = .025$). Our results indicated that the PD and HC groups' results differed only for the vertical modification type, with a lower accuracy ($U = 24$, $z = -1.97$, $p = .02$) and slower reaction times ($U = 9$, $z = 3.10$, $p = .01$) in the PD group. No group differences were found for accuracy and RTs for pictures with horizontal modifications (all $p > .1$). The Wilcoxon signed-rank analysis revealed

Table 3
Average face inversion effect (FIE) for the healthy controls (HC) and the Parkinson's disease patients (PD) for each emotion. M: Mean; SEM: standard error of the mean.

	PD		HC		*p* value[a]
	M	SEM	*M*	SEM	
Mean FIE	45.0	9.0	65.0	7.7	.008
Happy	9	9.9	10	8.2	.7
Anger	20	35.6	51	21.3	.004
Disgust	24	26.7	31	18.5	.5
Fear	18	25.3	51	30.7	.02
Neutral	11	13.7	18	13.2	.3

[a] *p* value: Mann–Whitney *U* test.

Table 4
Average accuracy (%) and reaction times (ms) for the healthy controls (HC) and the Parkinson's disease patients (PD) for Horizontal and Vertical dimension in the facial configural task. M, mean; SEM, standard error of the mean.

		PD		HC		*p* value[a]
		M	SEM	*M*	SEM	
Accuracy (%)	Horizontal	45.0	9.0	65.0	7.7	.11
	Vertical	74.4	3.8	85.6	4.5	.05
Reaction times (ms)	Horizontal	1380	134	1044	103	.17
	Vertical	1302	88	884	59	.002

[a] *p* value: Mann–Whitney *U* test.

that for both groups, vertical modifications were detected more easily than horizontal ones (all $p < .01$).

3.4. Correlations

Finally, to find out if the performance of PD patients is associated with the severity of their symptoms, we computed Spearman's rank correlation between the d' index in each task and (1) patients' characteristics (severity of the disease, disease duration) and (2) neuropsychological data. No correlation was significant. To explore whether performance on facial emotion recognition tasks was linked to configural processing, a correlation between the d' index on upright emotional faces and the d' index on configural faces was conducted for each emotion, including both groups. Analyses showed a positive correlation between these two tasks for anger (Rho = 0.66, $p < .05$), disgust (Rho = 0.46, $p < .05$) and fear (Rho = 0.73, $p < 05$).

4. Discussion

Some studies have shown facial emotion recognition impairments in PD patients. The present study aimed at exploring the cognitive changes that could be responsible for these deficits. Given the implications of configural processing for facial emotion recognition (Calder & Jansen, 2005; Calder et al., 2000; McKelvie, 1995; Prkackin, 2003) and previous results providing evidence of configural processing alteration in PD (Cousins et al., 2000), we hypothesized that patients' deficits in facial emotion recognition would be related to a specific alteration of their configural processing abilities. To assess this hypothesis, (i) facial emotion recognition was compared in patients suffering from PD and controls, (ii) the same task was proposed when faces were upside-down to explore the inversion effect, and (iii) the ability to detect specific configural modifications was investigated in both groups.

First, patients with PD had emotion discriminability impairments for fear and anger. These results are consistent with previous studies concerning fear (Kan et al., 2002; Sprengelmeyer et al., 2003) and anger recognition (Clark et al., 2008; Dujardin et al., 2004; Lawrence et al., 2007; Sprengelmeyer et al., 2003). PD patients may be particularly impaired at recognizing negative emotions (anger, fear and disgust) because of their dysfunctions in the ventral striatum, amygdala, insula and orbital frontal cortices, which are all involved in recognition of these emotions (see Adolphs, 2002 for a review; Phan, Wager, Taylor, & Liberzon, 2002 and Fusar-Poli et al., 2009 for meta-analyses). Nevertheless, it is noteworthy that anger impairment could also be attributable to a difficulty effect since anger was the most difficult emotion to discriminate in HC (in line with previous results, Calder et al., 2003; see Ruffman, Henry, Livingstone, & Phillips, 2008 for a review). In the present study, performance on disgust discriminability did not significantly differ between groups. This result does not replicate previous findings showing a severe and/or selective impairment for this emotion in PD patients (Kan et al., 2002; Suzuki et al., 2006), although some studies failed to report disgust recognition impairments in PD (Clark et al., 2008; Martínez-Corral et al., 2010). Such discrepancies could be explained by patients' characteristics, especially their dopaminergic state (drug on versus drug off). Indeed, dopamine replacement therapy reduces disgust recognition deficits (Sprengelmeyer et al., 2003) and could compensate for the expected recognition deficit for disgust in the present study.

A second result concerns the inversion effect for facial emotion discriminability. First, the FIE was replicated in controls: discriminability dropped drastically when faces were inverted consequently to a disruption of configural processing when faces are upside-down (see Maurer et al., 2002; Rossion, 2008 for reviews). In the latter case, configural processing seems to have been replaced by a featural strategy, which is not sufficient to recognize facial emotions (McKelvie, 1995), especially negative emotions requiring greater perceptual processing resources (Prkackin, 2003). FIE was smaller in PD than HC, for anger and fear, suggesting that PD alters configural processing. Consistently, anger and disgust were confused in the upright position: if patients rely more heavily on featural information (e.g., lowered eyebrows), they would have difficulty discriminating anger from disgust, given that both display lowered eyebrows. However, the FIE reduction in PD could merely reflects their facial emotion recognition impairment in the upright condition, instead of a configural processing impairment. Indeed, FIE differed in recognition of anger and fear that is for emotions in which the PD group was impaired in the upright condition.

Although an alteration of configural processing could not be affirmed from the FIE results, the facial configuration task provided arguments supporting our main hypothesis. Indeed, PD group less accurately discriminates modified faces than do controls, suggesting that PD affects the ability to detect second-order modifications. Regarding the modification type, both groups performed better (i.e., accuracy and reaction time) in detecting second-order modifications made on the vertical axis than on the horizontal one. This finding replicates our previous study, which showed preserved recognition for vertically modified faces in normal aging (Chaby et al., 2011). Nevertheless, patients with PD were less accurate and slower than controls to detect vertical modifications, which is known to be a fundamental component of face individuation (Goffaux, 2008). This result supports the hypothesis of a configural processing alteration, at least in the present PD patient sample. Consistently, basal ganglia which are involved in the dopaminergic depletion in PD patients, have reciprocal connections with fusiform regions (Geday et al., 2006). Yet, fusiform gyri are known to be implied in face processing (Kanwisher et al., 1997), suggesting that the dopaminergic depletion could lead to a dysfunction in cerebral regions related to face processing.

Moreover, correlation analyses showed that, overall, the upright expression recognition task and the configural task were positively correlated for anger, disgust and fear, suggesting a link between emotion recognition and configural processing. It seems that configural processing is required in emotion recognition, to disambiguate a number of shared features (e.g. "lowered eyebrows", Calder et al., 2000; Henley et al., 2008; Simon, Craig,

Gosselin, Belin, & Rainville, 2007). Thus, configural processing as assessed by the facial configuration detection task is related to emotion recognition, suggesting that an alteration of the configural processing could lead to reduced emotion recognition, especially for negative emotions.

The main results of the present study are: (1) PD is associated with an impairment of anger and fear recognition from faces that probably leads to a reduced FIE effect for those emotions; (2) a detection alteration of second-order modifications; (3) a positive correlation between emotion recognition and facial configuration detection performances. Taken together, these results suggest a configural processing decline in our PD sample. In contrast to previous studies showing preserved facial processing in PD patients coupled with impaired facial emotion processing (Clark et al., 2008; Lawrence et al., 2007; Sprengelmeyer et al., 2003) or impaired face memory (Kida, Tachibana, Takeda, Yoshikawa, & Okita, 2007), the present study suggests a configural processing alteration, especially in the processing of second-order information. These discrepancies could be ascribable to task differences; major studies have assessed facial perceptive abilities using the Benton Facial Recognition Test (Benton et al., 1983), a matching identity task that does not directly assess configural processing. Nevertheless, some of the limitations of the study and alternative hypotheses need to be discussed. The hypothesis of a configural processing decline in PD could be first related to the fact that PD patients present a reduced visual scanning area during viewing visual images (Matsumoto et al., 2011). However, this issue remains discussed and needs further considerations since divergent results were obtained. For example, Clark, Neargarder, and Cronin-Golomb (2010) have reported that PD patients show only subtle differences in visual scanning of facial expressions when fearful faces were displayed. Furthermore, ocular movements seem partially preserved in Parkinson's disease (Pierrot-Deseilligny & Rivaud-Pechoux, 2003), at least for patients receiving dopamine replacement therapy (Marino, Lanzafame, Sessa, Bramanti, & Bramanti, 2010). Second, the impairment of global processing abilities in PD could interfere with the configural processing abilities. Yet, such impairment has been reported in patients with left body side of motor onset (Schendan et al., 2009) while our sample is mainly constituted of right body side of motor onset. Given the small sample size, it would be interesting to further examine this issue. Third, the two experimental tasks rely on several cognitive processes. The possibility that facial emotion recognition deficits could be due to a more general deficit in visuospatial ability was ruled out by the absence of visuospatial impairments in our PD group. Although, patients presented an executive dysfunction, neither the facial emotion recognition impairment nor the detection of second-order modifications was related to the executive functioning. The potential confounding effect of decision-making (Brand et al., 2004) or categorization impairments in PD (Filoteo, Maddox, Ing, & Song, 2007; Price, 2006) were not controlled for the present study. However, Clark et al. (2008) showed that facial emotion recognition deficits are not related to categorization abilities. Similarly, the potential influence of working memory could be implicated in participants' performances on the configural task given the sequential design (500 ms between the target and the probe). Future studies need to make further neuropsychological investigations to clarify the influence of attention and executive functions on such experimental tasks. Finally, the small number of participants limits the generalization and further studies are required to confirm these preliminary results.

In summary, the present study suggests that (1) patients with Parkinson's disease have deficits in facial emotion recognition, especially for negative emotions, (2) the configural processing seems altered in PD, in particular regarding vertical second-order information, (3) configural processing and emotion recognition are positively correlated. Although these results need to be replicate with a larger sample, a better knowledge about the processes involved in emotion recognition deficits could have clinical implications. Indeed facial expressions convey information about the internal states of others and are crucial for interpersonal communication (Carton et al., 1999), social relationships (Clark et al., 2008) and empathy (Rankin, Kramer, & Miller, 2005).

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